# RESEARCH PLAN PROPOSAL

## Theoretical and experimental investigations of cycloaddition reactions of imidazo[1,2-*a*]pyridines and related heterocycles

For registration to the degree of
Doctor of Philosophy

**IN THE FACULTY OF SCIENCE**

## THE IIS UNIVERSITY, JAIPUR


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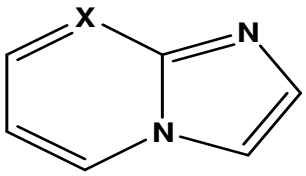
July, 2012

# TOPIC: Theoretical and experimental investigations of cycloaddition reactions of imidazo[1,2-*a*]pyridines and related heterocycles

## ❖ INTRODUCTION

Heterocycles form one of the most important and well investigated classes of organic molecules owing to their occurrence in living organisms and a wide range of biological activity. The key role in heterocyclic chemistry belongs to heteroaromatic structures, in particular to five- and six-membered rings and their fused-ring derivatives. It is well known that the difference in chemical behavior between five- and six-membered rings is accounted for by different aromaticities and different π-excessive or π-deficient characters of their electronic structures e.g. pyrrole and pyridine.[1]

Imidazo[1,2-*a*]pyridines or 1-azaindolizines **(1)** and the related imidazo[1,2-*a*]pyrimidines **(2)** have received significant attention from the pharmaceutical industry owing to their interesting biological activities displayed over a broad range of therapeutic classes,[2] showing antiulcer,[3] antiviral,[4-6] antifungal[7] and anti-inflammatory[8] activities.




1. X = CH
2 .X = N

**Figure 1.**

The most commonly used method for the synthesis of imidazo[1,2-*a*]pyridines and imidazo[1,2-*a*]pyrimidines involves cyclocondensation of 2-aminopyridines or 2-aminopyimidines with α-halocarbonyl compounds.[6, 9-14] Although several other methods of synthesis have also been reported,[15-21] they are found to be more cumbersome.

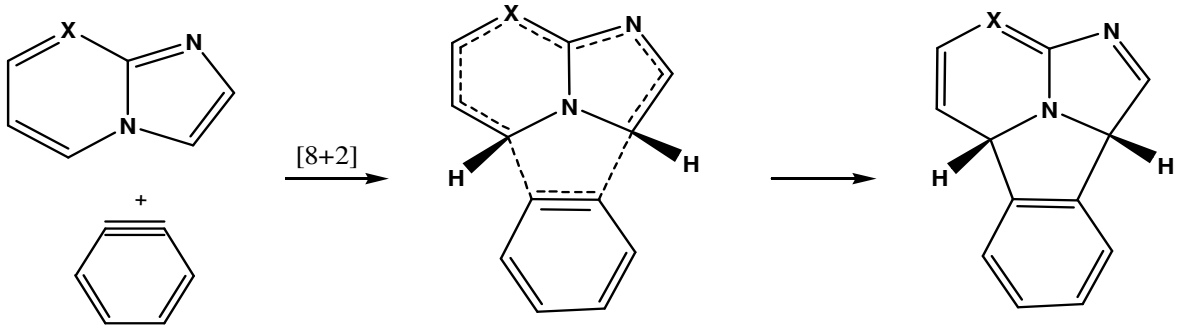
Like indolizine,[1] imidazo[1,2-*a*]pyridine and imidazo[1,2-*a*]pyrimidine are composed of a π-excessive five-membered ring and a π-deficient pyridine ring with only one bridgehead nitrogen. Literature survey reveals that though a number of [8+2] cycloaddition reactions of indolizine with a variety of alkenes and alkynes have been accomplished successfully,[1] no [2+4] cycloaddition has been reported so far. In contrast to indolizine,[22-35] the reactivity of imidazo[1,2-*a*]pyridine and imidazo[1,2-*a*]pyrimidine has been investigated experimentally or theoretically sparsely.

The presence of an additional pyridine type nitrogen (N1) in the five-membered ring of imidazo[1,2-*a*]pyridine and imidazo[1,2-*a*]pyrimidine may be expected to decrease the electron rich character of this ring, as its own lone-pair is not involved in the delocalisation. Moreover, the presence of N1 in the five-membered ring offers the possibility of decreasing the electron-density through its alkylation or coordination to the Lewis acid such as $AlCl_3$.

## ❖ REVIEW OF LITERATURE

### ➢ International Status

Literature survey reveals that only one [8+2] cycloaddition of imidazo[1,2-*a*]pyridine and imidazo[1,2-*a*]pyrimidine has been reported so far. Cossio and coworkers[36] reported the experimental and theoretical results of [8+2] cycloadditions of imidazo[1,2-*a*]pyridines and imidazo[1,2-*a*]pyrimidines with benzyne. The [8+2] cycloaddition steps are essentially barrierless and the aromatization steps occur via highly synchronous aromatic transition structures (**Scheme 1**).




a. X = CH
b. X = N

**Scheme 1.**

### ➢ National Status

According to our knowledge, no other research group is working on these heterocyclic systems.

## ❖ JUSTIFICATION AND RELEVANCE:

- Theoretical studies will be used for molecular modeling of imidazo[1,2-*a*]pyridine and imidazo[1,2-a]pyrimidine that is, its reactivity will be tuned by appropriate substitution.

- Synthesis of new heterocyclic compounds which may show interesting bioactivities.

- Identification of these new products by spectral techniques will enrich the existing knowledge in the chemistry.

## ❖ OBJECTIVES

1. Theoretical investigation of dienophilic reactivity of C(2)=C(3) functionality present in imidazo[1,2-*a*]pyridine and imidazo[1,2-*a*]pyrimidine and its tuning by introducing various substituent groups such as $NO_2$, $CF_3$, $CH_3$, etc. in the five- or six-membered rings.

2. Effect of N1 alkylation or its coordination to a Lewis-acid on the dienophilic reactivity of C(2)=C(3) functionality.

3. Theoretical investigation of dienophilic reactivity of C(2)=C(3) towards reverse electron-demand Diels-Alder reaction using electron-deficient heterodienes.

4. Normal electron-demand (NED) and reverse electron-demand (RED) Diels-Alder reactions of substituted imidazo[1,2-*a*]pyridines and imidazo[1,2-*a*]pyrimidines experimentally.

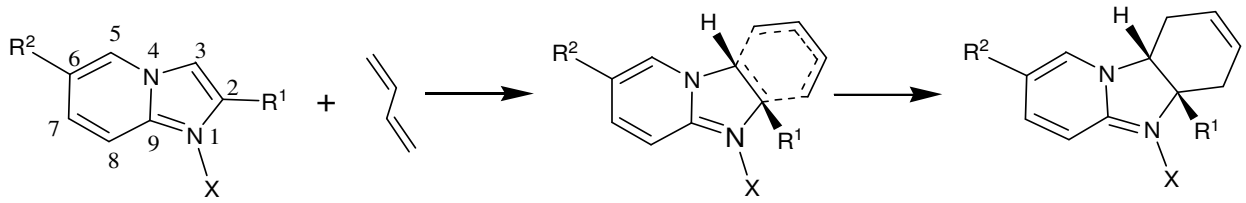
5. Investigation of [8+2] cycloadditions of imidazo[1,2-*a*]pyridines theoretically and experimentally.

## ❖ HYPOTHESIS

The proposed research work is based on the concept of [4+2] and [8+2] cycloaddition reactions, which are symmetry allowed according to Woodward-Hoffmann rule.

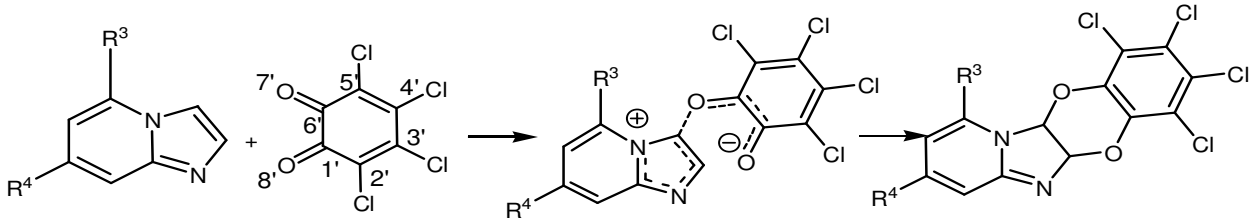
## ❖ PLAN OF WORK AND METHODOLOGY

1. Determination of activation barriers and energies of reactions for normal electron-demand (NED) and reverse electron-demand (RED) Diels-Alder reactions of imidazo[1,2-*a*]pyridine and its following derivatives:



| Reaction no./1 | **1/a** | **2/b** | **3/c** | **4/d** | **5/e** | **6/f** | **7/g** | **8/h** | **9/i** | **10/j** | **11/k** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **$R^1$** | H | $CF_3$ | $CH_3$ | $NO_2$ | H | H | H | H | H | H | H |
| **$R^2$** | H | H | H | H | $CF_3$ | $CH_3$ | $NO_2$ | H | $NO_2$ | H | H |
| **X** | - | - | - | - | - | - | - | $AlCl_3$ | $AlCl_3$ | $CH_3$ | $CH_2Ph$ |

**Scheme 2. Theoretical investigation of NED DA reactions**




**1** **TCQ** **TS** **Pr**

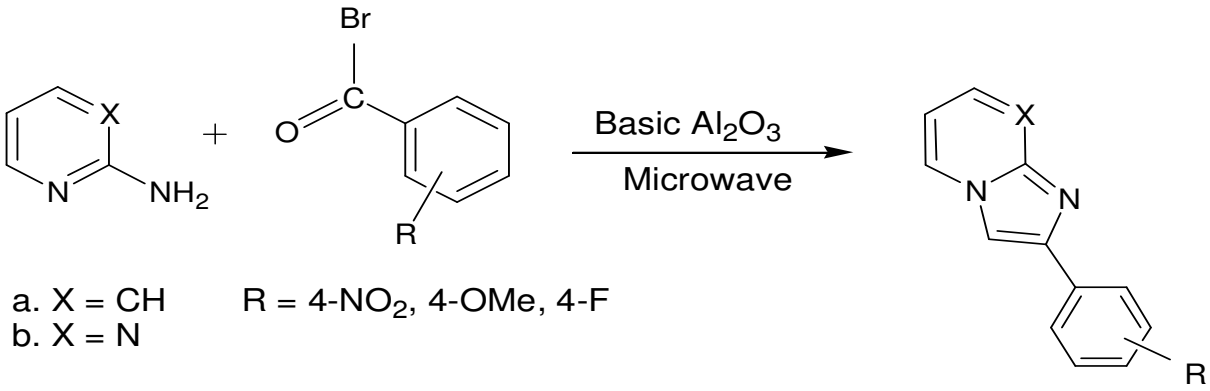
| Reaction no./1 | **12/l** | **13/m** | **14/n** | **15/0** | **16/p** |
|---|---|---|---|---|---|
| **$R^3$** | H | $NH_2$ | OMe | H | H |
| **$R^4$** | H | H | H | $NH_2$ | Ome |

**Scheme 3. Theoretical investigation of RED DA reactions**

2. Determination of activation barriers and energies of reactions for the DA reactions of imidazo[1,2-*a*]pyrimidines.

3. Synthesis of appropriately substituted imidazo[1,2-*a*]pyridines and imidazo[1,2-*a*]pyrimidines.

On the basis of the theoretical results, those substituted imidazo[1,2-*a*]pyridines and imidazo[1,2-*a*]pyrimidines will be synthesized which are expected to undergo DA reactions.




**Scheme 4.**

4. Normal electron-demand (NED) Diels-Alder reactions of imidazo[1,2-*a*]pyridines and imidazo[1,2-*a*]pyrimidines will be carried out with following 1,3-dienes-

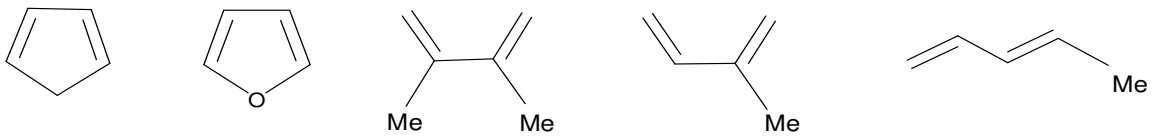
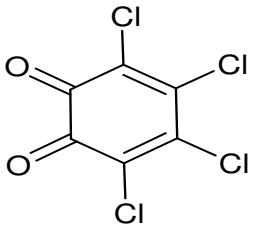


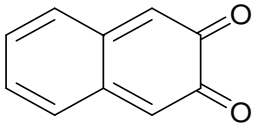

**Figure 2.**

5. Reverse electron-demand (RED) Diels-Alder reactions of unsubstituted and substituted imidazo[1,2-*a*]pyridines and imidazo[1,2-*a*]pyrimidines will be carried out with the following orthoquinones-

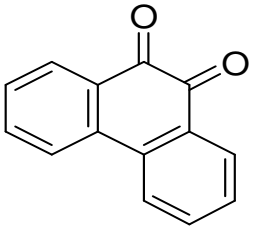
a. Tetrachloro-o-benzoquinone




b. Naphthoquinone




c. Penanthrenequinone




d. 3,5-Di(*tert*-butyl)-o-benzoquinone

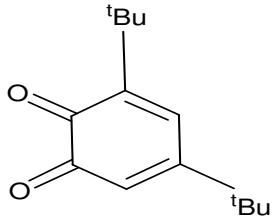



**Figure 3.**

6. Stereoselectivity and regioselectivity in the above reactions would be investigated theoretically and experimentally.

7. Investigation of [8+2] cycloadditions of imidazo[1,2-*a*]pyridines theoretically and experimentally.

8. Microwave assisted tandem synthesis of imidazo[1,2-*a*]pyridines and their [8+2] cycloaddition.

## ❖ YEARWISE PLAN OF WORK

- **First year:** Theoretical and experimental work on imidazo[1,2-*a*]pyridines.
- **Second year:** Theoretical and experimental work on imidazo[1,2-*a*]pyrimidines.
- **Third year**: Compilation and publication of the research work.

## ❖ PLACE OF WORK AND FACILITIES AVAILABLE

Department of Chemistry, IIS University, Jaipur. A modern well equipped laboratory, with modest instruments is available.

## ❖ LIMITATION AND ALTERNATIVE PLAN OF STUDY

The non-availability of multinuclear NMR spectrometer is the main limitation. We shall try to take the help of the institutions where this instrument is available.

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